CATALYST FOR PREPARATION OF UNSATURATED ALDEHYDE AND UNSATURATED CARBOXYLIC ACID

Technical field to which the invention belongs

This invention relates to catalyst for preparation of unsaturated aldehyde and unsaturated carboxylic acid. More particularly, the invention relates to a catalyst which is suitable for use in production of methacrolein and methacrylic acid, or acrolein and acrylic acid, by vapor-phase catalytic oxidation of isobutylene, tertiary butanol (which hereafter may be identified as t-butanol) or propylene. The invention also relates to processes for producing these unsaturated aldehydes and unsaturated carboxylic acids, using said catalyst.

Prior art

Many proposals have been made for catalysts to be used in the occasion of vapor-phase catalytic oxidation of isobutylene, t-butanol or propylene to produce respectively corresponding unsaturated aldehyde and unsaturated carboxylic acid.

It is already known that the yield improves when the catalyst shape is changed from pellets to rings. For example, JP 59 (1984)-46132 A (= US 4,511,671 A, EP 102,641 A1) has disclosed, as merits of adopting a specific ring form: (1) conversion improves due to increase in geometrical surface area, (2) yield improves because the reduced catalyst wall thickness enhances heat-removing effect, (3) pressure loss decreases, and (4) catalyst life is extended due to decrease in thermal load. For still increasing these effects, thinning the ring thickness is preferred. Reduction in the thickness, however, invites decrease in mechanical strength and causes such problems as, for example, when finished ring-formed catalyst is kept in a drum can, the catalyst at the bottom of the can break and become useless, or they may break when they are charged in reaction tubes and scattering in pressure loss among the reaction tubes increases.

As a method for improving strength of catalysts, it is known to add a fibrous material. For example, JP 51(1976)-20357 B

relating to vanadium pentoxide catalyst, copper-chromic acid catalyst, nickel-diatomaceous earth catalyst and manganese-chromic acid catalyst, discloses a method of adding a fibrous material, for example, blue asbestos, to the catalyst powder obtained through drying or calcination and subsequent pulverization. However, effect of adding a fibrous material to catalysts comprising molybdenum and bismuth as the essential ingredients is unknown. Also as to ring-formed catalyst, addition of fibrous material gives rise to a problem of increased scattering in mechanical strength among individual catalyst rings, while their mechanical strength can be improved.

JP 59 (1984)-183832 A (= US 4,564,607 A) discloses a method of using whiskers having an average diameter not more than 5μm as a reinforcement, in preparation of heteropolyacid-based catalyst. Whereas, as to catalyst comprising molybdenum and bismuth as the essential ingredients, addition of whiskers results in yield reduction, while improving catalyst strength.

JP 6 (1994)-381 A (= US 5,532,199 A, EP 574,895 A1) discloses a method of using inorganic fibers having an average diameter of 2–200μm as assistant carrier, in preparing carried catalyst containing molybdenum and bismuth as essential ingredients. This method aims at preparation of carried catalyst in which the carrier carries a large amount of the catalyst, and for that purpose a method of preparation must be such that a slurry formed by dispersing catalytically active ingredients and inorganic fibers in a liquid is deposited on a carrier and at the same time the liquid is vaporized and evaporated. This preparation method, however, is not necessarily easy of operating, and the catalytic activity varies depending on variation in preparation conditions. Hence, there is a problem of difficulty in preparing catalyst which exhibits uniform catalytic performance.

Problems to be solved by the invention

Accordingly, therefore, the object of the present invention is to solve the above problems in the prior art, by providing a catalyst suitable for catalytic vapor-phase oxidation of isobutylene, t-butanol

or propylene to produce corresponding unsaturated aldehyde and unsaturated carboxylic acid, i.e., a catalyst which excels in mechanical strength, is capable of providing the object products at high yield, and shows little deterioration in catalytic performance with time.

Means to solve the problems

Through our research work we have come to find that a catalyst for production of unsaturated aldehyde and unsaturated carboxylic acid, which is obtained by shaping a catalyst composition containing as active ingredients at least molybdenum and bismuth into rings and which additionally contains in the catalyst composition inorganic fibers such as glass fiber, alumina fiber, silica fiber, carbon fiber and the like, can accomplish the above object. The present invention is completed based on the above knowledge.

Thus, according to the invention, a catalyst for production of unsaturated aldehyde and unsaturated carboxylic acid is provided, which is characterized in that it consists of ring-shaped bodies comprising a catalytic composition containing as active ingredients at least molybdenum and bismuth, and inorganic fibers.

According to the invention, furthermore, a process is provided, which is characterized by using the above catalyst in catalytic vapor-phase oxidation of isobutylene, tertiary butanol or propylene with molecular oxygen, whereby producing respectively corresponding methacrolein and methacrylic acid or acrolein and acrylic acid.

The reason why the addition of inorganic fibers according to the present invention achieves improvements not only in the catalyst's mechanical strength but also in the catalytic performance, as well as inhibition of catalyst's deterioration with time is not fully clear yet. Presumably, because the catalyst composition is diluted with the inorganic fibers, the heat generated during the reaction is dispersed, sequential reactions are inhibited, and thermal degradation of the catalyst is inhibited. Also in view of the observation that the improvement in the catalyst's mechanical

strength is achieved when the added inorganic fibers have a specific size, it is presumed that the inorganic fibers are adequately dispersed in the catalyst to maintain an adequately mixed and contacted condition with the catalyst composition.

Embodiments of the invention

The catalyst of the present invention is of the type normally referred to as shaped catalyst, which is in the form of ring-shaped catalyst made of a catalyst composition containing molybdenum and bismuth as essential ingredients, and inorganic fibers. It is not a so called carried catalyst, formed by carrying a catalyst composition on a carrier.

As typical examples of the catalyst composition, those expressed by the following general formula (1) may be named:

$$Mo_a Bi_b Fe_c A_d B_e O_x \qquad \cdots (1)$$

(in which Mo is molybdenum; Bi is bismuth; Fe is iron; A is at least one element selected among nickel and cobalt; B is at least an element selected among alkali metal elements, alkaline earth metal elements, thallium, phosphorus, tellurium, antimony, tin, cerium, lead, niobium, manganese, arsenic, zinc, silicon, aluminium, titanium, zirconium and tungsten; O is oxygen; a, b, c, d, e and x stand for the respective atomic numbers of Mo, Bi, Fe, A, B and O, where a is 12, b is 0.1–10, c is 0.1–20, d is 2–20; e is 0–30 and x is a numerical value determined by the extents of oxidation of the other elements).

The catalyst composition expressed by the general formula (1) can be formulated following those methods generally used for preparing this type of catalyst. As the starting materials of each of the ingredients, oxides of the ingredients or salts of the ingredients which form oxides under heating, such as nitrates, ammonium salts, organic acid salts, carbonates, alkali metal salts and the like, may be suitably selected for use.

As inorganic fibers, glass fibers, ceramic fibers, carbon fibers and the like may be used, of those, glass fibers, alumina fibers

and silica fibers are preferred. In particular, glass fibers are conveniently used. More than one kind of inorganic fibers may be suitably used in combination, or those of different average fiber lengths or fiber diameters may be used in combination. Where glass fibers are used, those of different glass compositions may be suitably used in combination.

As such inorganic fibers, those having an average fiber length of 50μm–1.5mm, preferably 50μm–1.2mm, and an average fiber diameter of 2μm–20μm, preferably 5μm–15μm, are conveniently used. It is sufficient that the average fiber length falls within the above range in the completed shaped catalyst. Therefore, besides using inorganic fibers whose average length is advancedly adjusted to 50μm–1.5mm, it is permissible to mix inorganic fibers having an average length exceeding 1.5mm with a part or the whole of a catalytic composition and break the fibers under vigorous agitation to eventually render their average length to fall within the range of 50μm–1.5mm. The latter practice, however, tends to aggravate dispersibility of the inorganic fibers. Use of inorganic fibers whose average fiber length and average fiber diameter deviate from the ranges of 50μm–1.5mm and 2μm–20μm, respectively, gives rise to problems such as that catalyst of uniform performance cannot be obtained, and therefore is objectionable.

Suitable inorganic fiber content based on the weight of the catalyst is 0.01–30%, preferably 0.05–20%, inter alia, 0.1–10%, the percentages being by weight. Where the content is too low, the effect of improving the catalyst's mechanical strength is insufficient, and where it is too high, the catalyst composition contained in the catalyst becomes less and the catalytic performance is degraded.

Those catalysts of the present invention can be prepared following those methods generally used for preparing known catalysts for production of unsaturated aldehyde and unsaturated carboxylic acid, excepting the point of adding inorganic fibers to catalyst composition and shaping the system into rings.

More specifically, a satisfactory catalyst can be prepared by adding inorganic fibers to, for example, a catalyst composition

expressed by said general formula (1), and then shaping the system into rings by a conventionally used shaping method such as extrusion molding, pressing or the like. Manner of adding the inorganic fibers is not critical, and any method may be used so long as it is capable of securing uniformly dispersed presence of the added inorganic fibers in the finished catalyst. For example, inorganic fibers may be added to the starting compounds for a catalyst composition and the resulting slurry is dried and shaped, followed by ~~calcinations~~ calcination or a catalyst composition is dried, calcined and pulverized, and inorganic fibers are added to the resulting powder, thoroughly mixed and the mixture is shaped. In particular, the former method is favorable because it gives a catalyst exhibiting improved mechanical strength, yield of object products and catalyst life, with good reproducibility. The ~~calcinations~~ calcination treatment is normally conducted at temperatures ranging 400–800°C. The inorganic fibers may be added all at once or in divided portions. For example, a part of them may be added to a slurry containing starting compounds and the rest, to the dried and calcined powder.

In the occasion of shaping, conventionally used binder such as polyvinyl alcohol, stearic acid, ammonium nitrate, graphite, water, alcohol and the like may be used if necessary.

The ring-formed catalyst grains preferably each has an outer diameter of 3–10mm, 0.1–0.7 time the outer diameter of an inner diameter and 0.5–2 times the outer diameter of a length (height).

The catalytic vapor-phase oxidation reaction according to the invention can be performed following generally practiced method for catalytic vapor-phase oxidation of ~~isobytylene~~ isobutylene, t-butanol or propylene using molecular oxygen, to produce corresponding methacrolein and methacrylic acid, or acrolein and acrylic acid, excepting the point that above-described shaped catalyst is used as the catalyst. For example, a gaseous mixture composed of 1–10 vol.% of isobutylene, t-butanol or propylene, 3–20 vol.% of molecular oxygen, 0–60 vol.% of steam and 20–80 vol.% of an inert gas such as nitrogen, carbon dioxide and the like may be introduced over said

shaped catalyst at a temperature within a range of 250–450°C, under normal pressure to 1Mpa and at a space velocity of 300–5,000h^{-1} (STP).

In practicing the catalytic vapor-phase oxidation according to the present invention, obviously such a method may be used as filling each reaction tube with two or more kinds of the catalysts differing in activity levels, which are prepared by varying the composition, calcining condition, size or shape of the catalysts, as stacked in layers so that the catalytic activity successively rises from the gas inlet toward the gas outlet of the reaction tube, to inhibit heat accumulation at hot spots, or any of various other known inhibition methods.

Effect of the invention

According to the invention, catalysts which are high in mechanical strength, capable of giving unsaturated aldehyde and unsaturated carboxylic acid, which are the object products, at high yields, and have uniform catalytic performance showing little decrease in catalytic activity (yield reduction) with time can be prepared with ease. According to the present invention, furthermore, acrolein and acrylic acid or methacrolein and methacrylic acid can be produced at high yields over long periods.

Examples

Hereinafter the invention is explained more specifically, referring to working examples. The conversions and yields as given in the Examples and Comparative Examples are defined as follows:

$$\text{comversion (mol\%)} = \frac{\text{(mol number of reacted starting material)}}{\text{(mol number of starting material)}} \times 100$$

$$\text{yield (mol\%)} = \frac{\text{(total mol number of formed unsaturated aldehyde and formed unsaturated carboxylic acid)}}{\text{(mol number of starting material)}} \times 100$$

The performance tests and shatter strength test of the catalysts were conducted by the following methods.

Catalytic performance test–1

One-hundred(100)ml of a catalyst was filled in a steel reaction tube of 25mm in inner diameter, into which a gaseous mixture composed of 6 vol.% of isobutylene, 13 vol.% of oxygen, 15 vol.% of steam and 66 vol.% of nitrogen was introduced. The reaction was conducted at a space velocity of $1600h^{-1}$ and a reaction temperature of 340°C. The reaction gas after 30 hours was analyzed.

Catalytic performance test–2

Fifteen-hundred(1,500)ml of a catalyst was filled in a steel reaction tube of 25mm in inner diameter, and into which a gaseous mixture composed of 6 vol.% of isobutylene, 13 vol.% of oxygen, 15 vol.% of steam and 66 vol.% of nitrogen was introduced. The reaction was conducted at a space velocity of $1600h^{-1}$ and a reaction temperature of 340°C. The reaction gas after 8,000 hours was analyzed.

Catalytic performance test–3

One-hundred(100)ml of a catalyst was filled in a steel reaction tube of 25mm in inner diameter, and into which a gaseous mixture composed of 7 vol.% of propylene, 14 vol.% of oxygen, 25 vol.% of steam and 54 vol.% of nitrogen. The reaction was conducted at a space velocity of $1800h^{-1}$ and a reaction temperature of 310°C. The reaction gas after 30 hours was analyzed.

Shatter strength test

Thirty(30)g of a catalyst was dropped from the top of a perpendicularly erected stainless steel pipe of 25mm in inner diameter and 5m in length, and received with a 4-mesh sieve. The weight of the catalyst remained on the sieve was measured and the shatter strength of the catalyst was determined, applying the following equation:

$$\text{Shatter strength}(\%) = \frac{(\text{weight of catalyst remained on the sieve})}{(\text{weight of dropped catalyst})} \times 100$$

Example 1

Six-thousand(6,000)ml of water was heated to 40°C, and into which 2118g of ammonium paramolybdate and 530g of ammonium paratungstate were dissolved under stirring. Thus a solution (liquid A) was prepared. Separately, 486g of bismuth nitrate was dissolved in aqueous nitric acid solution composed of 60ml of nitric acid (concentration: 65wt%) and 240ml of water to prepare another solution (liquid B). Again separately, 2912g of cobalt nitrate and 404g of ferric nitrate were dissolved in 2000ml of water to form a solution (liquid C), and 78.0g of cesium nitrate was dissolved in 400ml of water to form a solution (liquid D). Then into the liquid A under heating and stirring, the liquid B, liquid C and liquid D were added dropwise by the order stated, and mixed. Further 406g of 20wt% silica sol and 68.9g of alkali-free glass fibers of 10μm in average fiber diameter and 500μm in average fiber length were added to the mixture, followed by thorough stirring.

Thus obtained suspension was heated under stirring to evaporate the system to dryness, and the resulting solid matter was shaped into rings of 6.0mm in outer diameter, 1.0mm in inner diameter and 6.6mm in length each, which were calcined at 500°C for 6 hours while passing air, to provide a catalyst.

The composition of this catalyst excluding the glass fibers and oxygen was:

$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.4} Si_{1.35}$

and its glass fiber content was 2.0wt%.

The catalytic performance test–1 and shatter strength test were conducted using this catalyst. The catalytic performance, pressure loss during the reaction time and shatter strength of this catalyst are shown in Table 1.

Examples 2–9 and Comparative Examples 1–4

Example 1 was repeated except that the used glass fibers or shape of the catalyst were changed as shown in Table 1, to prepare catalysts.

The catalytic performance test–1 and shatter strength test were conducted using these catalysts. Their catalytic performance, pressure loss during the reaction time and shatter strength are shown in Table 1.

Table 1

	Inorganic Fibers	Added amount of inorganic fibers (wt%)	Catalyst shape outer diameter × inner diameter × length (mm)	Isobutylene conversion (mol%)	Total yield of methacrolein + methafcrylic acid (mol%)	Shatter strength (%)	Pressure loss during reaction time (kPa)
Example 1	Glass fibers (10μmØ / 500μm-long)	2.0	6.0 × 1.0 × 6.6	99.1	89.1	98.5	16.4
Example 2	Glass fibers (7μmØ / 500μm-long)	2.0	6.0 × 1.0 × 6.6	98.9	89.0	98.1	16.2
Example 3	Glass fibers (13μmØ / 500μm-long)	2.0	6.0 × 1.0 × 6.6	99.0	89.2	97.9	16.7
Example 4	Glass fibers (10μmØ / 150μm-long)	2.0	6.0 × 1.0 × 6.6	98.8	89.1	98.8	16.5
Example 5	Glass fibers (10μmØ / 3mm-long)	2.0	6.0 × 1.0 × 6.6	98.9	88.8	94.9	17.2
Example 6	Glass fibers (10μmØ / 500μm-long)	0.5	6.0 × 1.0 × 6.6	99.0	88.7	95.5	17.3
Example 7	Glass fibers (10μmØ / 500μm-long)	7.0	6.0 × 1.0 × 6.6	99.2	89.0	99.1	16.4
Example 8	Glass fiber mixture (10μmØ / 500μm-long & 10μmØ / 3mm-long))	2.0 2.0	6.0 × 1.0 × 6.6	98.9	89.6	99.0	16.8
Example 9	Glass fibers (10μmØ / 500μm-long)	2.0	5.0 × 3.0 × 5.5	99.2	90.2	95.4	13.1

Table 1 (continued)

	Inorganic Fibers	Added amount of inorganic fibers (wt%)	Catalyst shape outer diameter × inner diameter × length (mm)	Isobutylene conversion (mol%)	Total yield of methacrolein + methafcrylic acid (mol%)	Shatter strength (%)	Pressure loss during reaction time (kPa)
Comparative Example 1	—	—	6.0 × 1.0 × 6.6	99.0	88.2	90.4	18.1
Comparative Example 2	glass powder (40μmØ)	2.0	6.0 × 1.0 × 6.6	99.1	88.4	89.7	18.0
Comparative Example 3	silicon carbide (0.4μmØ / 40μm-long)	2.0	6.0 × 1.0 × 6.6	99.0	88.3	99.1	15.4
Comparative Example 4		—	5.0 × 3.0 × 5.5	98.9	89.0	75.0	18.2

Example 10

The catalytic performance test–2 was conducted using the catalyst of Example 1. The results were: isobutylene conversion, 90.2mol% and total yield of methacrolein plus methacrylic acid, 82.3mol%.

Comparative Example 5

The catalytic performance test–2 was conducted using the catalyst of Comparative Example 1. The isobutylene conversion was 85.1mol% and the total yield of methacrolein plus methacrylic acid was 76.6mol%.

Example 11

Into 6,000ml of water heated to 40°C, 2000g of ammonium paramolybdate and 50g of ammonium paratungstate were dissolved under stirring to form a solution (liquid A). Separately, 778g of bismuth nitrate was dissolved in an aqueous nitric acid solution formed of 100ml of nitric acid (concentration: 61wt%) and 400ml of water to provide a solution (liquid B). Again separately 1100g of cobalt nitrate, 824g of nickel nitrate and 572g of ferric nitrate were dissolved in 2000ml of water to form a solution (liquid C), and 7.6g of potassium nitrate was dissolved in 100ml of water to provide a solution (liquid D). Then into the liquid A under heating and stirring, the liquids B, C and D were added by the order stated under continual stirring and mixing, and further 242g of 20wt% silica sol and 151g of alkali-free glass fibers of 10μm in average fiber diameter and 500μm in average fiber length were added, followed by thorough stirring.

Thus obtained suspension was heated and stirred to be evaporated to dryness, and shaped into rings of 6.0mm in outer diameter, 1.0mm in inner diameter and 6.6mm in length each, which were calcined at 480°C for 8 hours while passing air, to provide a catalyst.

The composition of this catalyst excluding the glass fibers and oxygen was:

$Mo_{12}\ W_{0.2}\ Bi_{1.7}\ Fe_{1.5}\ Co_4\ Ni_3\ K_{0.08}\ Si_1$

and its glass fiber content was 5wt%.

The catalytic performance test–3 and shatter strength test were conducted using this catalyst to give a propylene conversion of 98.3mol%, total yield of acrolein plus acrylic acid of 91.8mol%, a pressure loss during the reaction time of 18.9kPa and a shatter strength of 98.9%.

Comparative Example 6

Example 11 was repeated except that no glass fiber was used, to provide a catalyst.

The catalytic performance test–3 and shatter strength test were conducted using this catalyst. The propylene conversion was 98.5mol%, total yield of acrolein plus acrylic acid was 90.9mol%, pressure loss during the reaction time was 21.6kPa and the shatter strength was 94.1%.

In the following Example 12 and Comparative Example 7, two kinds of catalysts exhibiting different activity levels were stacked and filled in the reaction tube in such a manner that the catalyst of the lower activity was located at the inlet side of the reaction tube and that of the higher activity, at the outlet side of the reaction tube, and the reaction was conducted.

Example 12

[Preparation of Catalyst 1 to be stacked]

Catalyst 1 for stacking was prepared as in Example 1, except that the amount of cesium nitrate was changed to 136.4g and the rings were shaped to have an outer diameter of 5.0mm, an inner diameter of 3.0mm and a length of 5.5mm each.

The composition of this catalyst excluding the glass fibers and oxygen was:

$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.7} Si_{1.35}$

and its glass fiber content was 2.0wt%.

The results of conducting the catalytic performance test–1 and shatter strength test using this catalyst are shown in Table 2.

[Preparation of Catalyst 2 to be stacked]

The procedures for preparing above Catalyst 1 were repeated except that the amount of cesium nitrate was changed to 19.5g, to prepare Catalyst 2 to be stacked.

The composition of this catalyst excluding the glass fibers and oxygen was:

$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.1} Si_{1.35}$

and the glass fiber content was 2.0wt%.

The results of conducting the catalytic performance test–1 and shatter strength test are shown in Table 2.

[Reaction]

The reaction was conducted under the same conditions to those of the catalytic performance test–2, through the reaction tube filled with 750ml of the Catalyst 1 at the gas inlet side and 750ml of the Catalyst 2 at the gas outlet side, forming a stack. The catalytic performance after 30 hours of the reaction is shown in Table 2.

<u>Comparative Example 7</u>

[Preparation of Catalyst 3 to be stacked]

Catalyst 3 was prepared in the same manner as the Catalyst 1 in Example 12, except that no glass fiber was added.

The results of conducting the catalytic performance test–1 and shatter strength test using this catalyst are shown in Table 2.

[Preparation of Catalyst 4 to be stacked]

Catalyst 4 was prepared in the same manner as the

Catalyst 2 in Example 12, except that no glass fiber was added.

The results of conducting the catalytic performance test–1 and shatter strength test using this catalyst are shown in Table 2.

[Reaction]

Filling 750ml of said Catalyst 3 at the gas inlet side of the reaction tube and 750ml of said Catalyst 4 at the gas outlet side thereof in a stack, the reaction was performed under the same conditions to those of the catalytic performance test–2. The catalytic performance after 30 hours of the reaction is shown in Table 2.

Table 2

		Catalyst composition	Inorganic Fibers	Added amount of Inorganic fibers (wt%)
Example 12	Catalyst 1	$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.7} Si_{1.35}$	Glass fibers (10μmØ / 500μm-long)	2.0
	Catalyst 2	$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.1} Si_{1.35}$	Glass fibers (10μmØ / 500μm-long)	2.0
	Reaction	Catalyst 1 : 750ml Catalyst 2 : 750ml		
Comparative Example 7	Catalyst 3	$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.7} Si_{1.35}$	—	—
	Catalyst 4	$Mo_{12} W_2 Bi_1 Fe_1 Co_{10} Cs_{0.1} Si_{1.35}$	—	—
	Reaction	Catalyst 3 : 750ml Catalyst 4 : 750ml		

Table 2 (continued)

		Catalyst shape outer diameter × inner diameter × length (mm)	Isobutylene conversion (mol%)	Total yield of methacrolein + methacrylic acid (mol%)	Shatter strength (%)	Pressure loss during reaction time (kPa)
Example 12	Catalyst 1	5.0 × 3.0 × 5.5	96.0	88.3	98.4	13.2
	Catalyst 2	5.0 × 3.0 × 5.5	99.5	88.1	98.0	13.0
	Reaction		99.5	91.8	—	12.9
Comparative Example 7	Catalyst 3	5.0 × 3.0 × 5.5	97.1	86.9	76.4	17.9
	Catalyst 4	5.0 × 3.0 × 5.5	99.8	86.4	74.3	18.4
	Reaction		99.7	90.2	—	18.5